SITE CONSIDERATIONS AND PILOT STUDIES FOR LAND DISPOSAL OF TREATED SEWAGE EFFLUENT

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Ontario

Ministry of the Environment

The Honourable
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Minister

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Deputy Minister

SITE CONSIDERATIONS AND PILOT STUDIES

FOR

LAND DISPOSAL OF TREATED SEWAGE EFFLUENT

BY

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ABSTRACT

The climatic constraints and recommended vegetation practices for land disposal of treated sewage effluent in Ontario are presented in this report. Differences between spray irrigation and overland runoff systems are discussed in terms of physiography and moisture requirements. A description of pilot studies for on-site determination of effluent loadings is included.

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SITE CONSIDERATIONS AND PILOT STUDIES FOR LAND DISPOSAL OF TREATED SEWAGE EFFLUENT

1. INTRODUCTION

Land disposal of effluent from activated sludge sewage treatment plants and waste stabilization ponds can be an effective method of reducing the pollutant load on a receiving stream during certain periods of the year; this method of disposal may be attractive to communities where suitable land is available at low cost.

Land application takes advantage of the combined capacities of the soil and vegetation to renovate effluent by filtration, adsorption, chemical precipitation, ion exchange, biochemical transformation and/or biological absorption. The mode of liquid application, which depends on both site conditions and the required degree of renovation, falls within one of the following categories:

(1) Rapid Infiltration Basins (RI): Underdrained basins of highly permeable soils (high percent sand and gravel) are sprayed or flooded with effluent primarily for suspended solids removal although nitrogen removal is achieved at the Flushing Meadows Project in Arizona (1) by intermittent flooding of a grassed basin.

(2) Ridge and Furrow Systems (R & F): Furrows between vegetated ridges are filled with effluent which is renovated by infiltration and evapotranspiration. These systems require flat terrain for even distribution of effluent.

(3) Spray Irrigation (SI): Fairly level soils with good permeability are uniformly irrigated with effluent by sprinklers, providing excellent renovation and generally enhanced growth of selected crops.

(4) Overland Runoff (OR): Sloping terrain of low permeability is flooded with thin sheets of effluent from sprinklers, distribution ditches or perforated pipes but provides less effective renovation than SI as only the vegetation and a thin layer of topsoil is available to the effluent.

This report discusses the climatic constraints and vegetation practices for land disposal of effluent as well as the differences between spray irrigation and overland runoff systems in terms of physiography and moisture requirements. A description of pilot studies for on-site determination of effluent loadings is included.

2. SITE CONSIDERATIONS

2.1 Climate

The climatic regions of Northern (4) and Southern (5) Ontario are shown in Figure 1. Isohyets for the period of May to September are shown in Figure 2. Thirty to fifty year summaries of the mean annual frost-free period, perennial-crop growing season and potential evapotranspiration are shown in Table 1.

The frost free period is the recommended limit for liquid application by SI. Outside this period, runoff is excessive due to high soil moisture content in the spring and natural precipitation exceeding evapotranspiration in the fall. Effluent disposal by OR systems can be carried out for the bulk of the growing season as it is the plants which provide most of the effluent renovation. Storage lagoons should be provided for effluent for the remainder of the year.

Climatic data may be used to estimate the amount of effluent which could be used to replenish the crop water deficit; this deficit usually occurs during the hot, dry months of July and August and is equal to the sum of the potential evapotranspiration and the soil moisture-holding capacity minus the May to September precipitation. The crop water deficit usually amounts to only a few centimetres of liquid per year; the volume of applied effluent which exceeds the deficit infiltrates and/or runs off depending on the soil and topography.

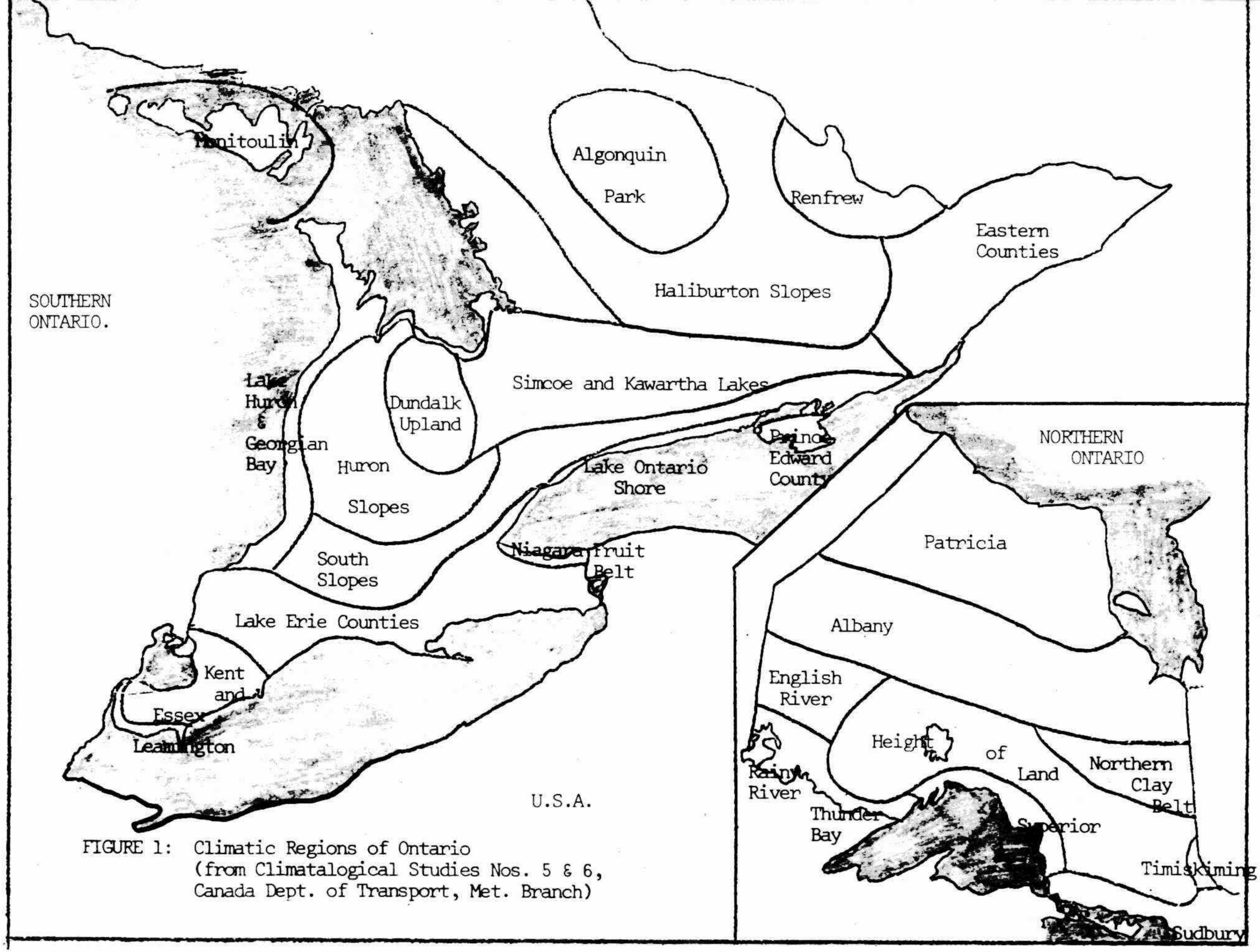


FIGURE 1: Climatic Regions of Ontario
(from Climatalogical Studies Nos. 5 & 6,
Canada Dept. of Transport, Met. Branch)

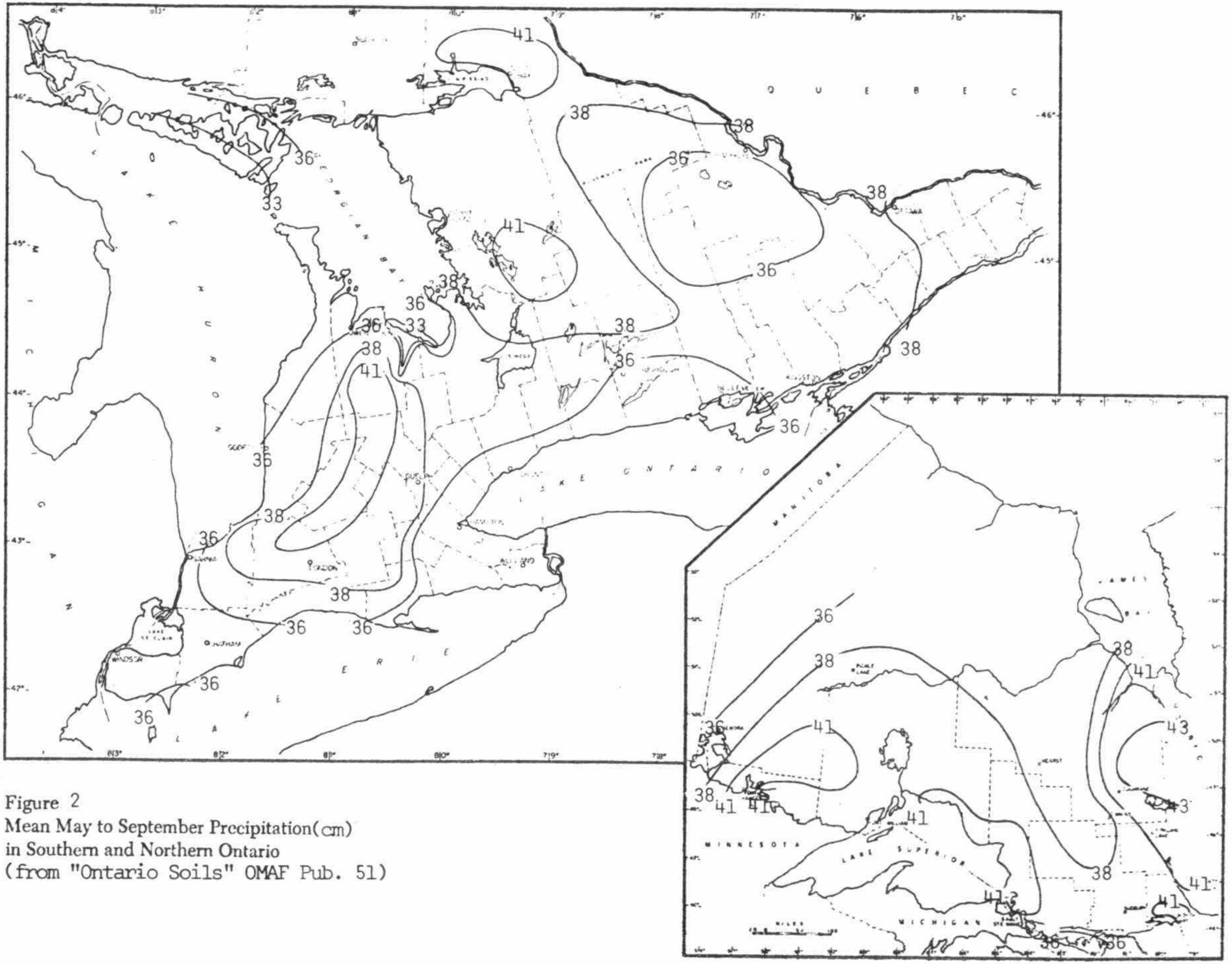


Figure 2
Mean May to September Precipitation(cm)
in Southern and Northern Ontario
(from "Ontario Soils" OMAF Pub. 51)

TABLE 1 CLIMATIC SUMMARY FOR ONTARIO*

	Mean Annual Frost-Free Period		Mean Annual Growing Season		Mean Annual Potential Evapotranspiration (cm)
	Dates	Days	Dates	Days	
Leamington	May 1 to Oct.20	172	Apr. 6 to Nov.12	221	66
Niagara Fruit Belt	May 5 to Oct.15	163	Apr.10 to Nov.10	215	64
Kent and Essex	May 5 to Oct.15	163	Apr. 8 to Nov.11	218	66
Lake Erie Counties	May 12 to Oct.10	151	Apr.10 to Nov. 8	213	64
Lake Ontario Shore	May 12 to Oct. 8	149	Apr.12 to Nov. 3	206	61
Prince Edward County	May 12 to Oct.10	151	Apr.12 to Nov. 5	208	61
Lake Huron, Georgian Bay	May 15 to Oct.10	148	Apr.15 to Nov. 5	205	61
South Slopes	May 15 to Oct. 5	143	Apr.13 to Nov. 3	205	61
Huron Slopes	May 20 to Sept.30	133	Apr.17 to Oct.31	198	58
Simcoe and Kawartha	May 18 to Sept.28	133	Apr.18 to Oct.28	194	58
Eastern Counties	May 15 to Sept.28	136	Apr.15 to Oct.28	197	61
Manitoulin	May 25 to Sept.28	126	Apr.23 to Oct.28	189	56
Muskoka	May 25 to Sept.25	123	Apr.22 to Oct.27	189	58
Renfrew	May 18 to Sept.25	130	Apr.18 to Oct.27	193	58
Dundalk Upland	May 31 to Sept.20	113	Apr.20 to Oct.25	189	56
Haliburton Slopes	May 25 to Sept.17	115	Apr.22 to Oct.24	186	56
Algonquin Park	May 31 to Sept.20	113	Apr.25 to Oct.21	180	53
Sudbury	May 31 to Sept.20	112	Apr.25 to Oct.24	183	56
Thunder Bay	May 31 to Sept.12	104	Apr.26 to Oct.17	175	53
Timiskiming	June 10 to Sept.13	96	Apr.27 to Oct.15	172	53
Superior	June 5 to Sept.15	103	May 6 to Oct.15	163	51
Northern Clay Belt	June 8 to Sept. 7	92	May 7 to Oct.13	160	51
English River	May 30 to Sept.15	108	May 3 to Oct.13	164	53
Height of Land	June 15 to Sept. 2	80	May 5 to Oct.13	162	48
Albany	June 12 to Sept. 5	86	May 15 to Oct. 8	154	46
Patricia	June 18 to Aug. 31	75	May 24 to Oct. 1	131	41

* from Climatological Studies Nos. 5 & 6, Canada Dept. of Transport, Met. Branch.

2.2 Physiography

2.2-1 Soil

The type and depth of soil available for land disposal are two major considerations when determining the mode of sewage effluent application. A list of the five predominant soil types in Ontario and their suitability to various application modes is shown below:

Soil	Potential Application Mode
Well drained sands	RI
Loamy Sands	SI
Light coloured loams and sandy loams with good drainage.	SI
Dark coloured loams and sandy loams with fair to poor drainage	SI or OR
Clay Loams	OR

An unsaturated soil zone of 2 to 3 metres (6) is required to protect the groundwater from bacteriological contamination and maintain an active aerobic root zone during operation of an SI system. The depth of this zone, which is initially determined by measuring the watertable at the beginning of the spray season, should be monitored regularly for the duration of the season to check that the irrigated effluent does not cause groundwater mounding above the recommended minimum depth of unsaturated soil. The depth of the unsaturated soil zone is not as critical in the operation of RI and OR systems as rapid infiltration basins are usually underdrained to prevent groundwater contamination and overland runoff systems are designed and operated to produce minimum infiltration.

2.2-2 Topography

The topography, soils and cover of a prospective disposal site correspond to a particular terrain (3) or runoff coefficient (Table 2) which is the third consideration when determining the mode of effluent application.

Sites with coefficients up to 0.35 are suitable for SI disposal, provided the unsaturated soil zone criteria are met, whereas sites with coefficients greater than 0.40 are more suited to OR disposal. Sites with coefficients between 0.35 and 0.40 may be used for low rate irrigation of effluent although problems with runoff or ponding may be expected depending on the slope of the land. Inconsistencies in the topography, such as depressions or ruts, should be avoided or filled to prevent stagnation or channeling of the effluent.

TABLE 2. VALUES OF RUNOFF COEFFICIENT*

Topography & Vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Rural Woodland			
Flat 0 to 5% Slope	0.10	0.30	0.40
Rolling 5 to 10% Slope	.25	.35	.50
Hilly 10 to 30% Slope	.30	.50	.60
Pasture			
Flat	.10	.30	.40
Rolling	.16	.36	.55
Hilly	.22	.42	.60
Cultivated			
Flat	.30	.50	.60
Rolling	.40	.60	.70
Hilly	.52	.72	.82

* from "CSP Technical Manual"

2.2-3 Drainage

The surface drainage characteristics of a disposal site may be determined by on-site survey and from either aerial photographs or topographical maps. Any waterbodies or courses within the drainage area of an SI disposal site should be protected by a buffer zone in case of runoff whereas waterbodies within an OR site should be expected to receive a volume of runoff approximately equal to the applied volume times the runoff coefficient.

The direction of groundwater flow (hydraulic gradient) should slope away from dug wells in the vicinity of a land disposal site and is determined by measuring watertable elevations at 3 points and establishing a contour line; a perpendicular to the contour line is the direction of slope (8). The flowrate or transmissibility of groundwater may be estimated by measuring the movement of tracers (tritium, chloride) injected into the groundwater. Effluent applications exceeding the sum of the transmissibility and local evapotranspiration rates could lead to excessive groundwater mounding and eventual surface flooding.

The zone of influence of drilled wells may be determined from pumping tests to show whether a connection exists between perched groundwater and deep aquifers.

2.3 Vegetation

2.3-1 General

Forests and brushland have high potential for wastewater disposal as the land value is relatively low compared to cultivated areas.

On arable land, perennial grasses (Brome, Orchard, Reed Canary and Timothy) are most suitable for both SI and OR disposal sites as they have fibrous root systems, are sod forming which aids in erosion control and provides for high infiltration rates, have a long period of growth and have a high uptake of nutrients (10). The order of preference for use of these grasses on disposal sites is as follows.

Order	Name	Comments (2)
1	Reed Canary	Tolerates excessive moisture and is highly productive for long term hay or pasture on poorly drained soils, or areas subject to prolonged periods of flooding; less palatable than other grasses; more acceptable to livestock when stored as silage or haylage rather than dry hay.
2	Timothy	Well adapted to heavier soil types and variably drained soils.
3	Brome	Highest digestability of grasses when cut at the "heads emerged" stage; superior for early pasture; good growth in fall.
4	Orchard	Requires well-drained sites to avoid winter kill; grows back immediately after cutting or grazing.

2.3-2 Moisture Requirements

Each soil-crop combination has a specific moisture requirement related to the moisture-holding capacity of the soil and the peak moisture-use rate and root-zone depth of the crop (7). Sewage effluent can provide this moisture as well as part of the PKN (phosphorus, potassium and nitrogen) requirements of the crop.

The amount of liquid effluent which should be applied by spray irrigation to maintain the soil at "Field Capacity" for perennial grasses is listed in Table 3. This amount must be applied with the "Irrigation Period" at a rate at which the soil will absorb the liquid, the "Recommended Application Rate". An SI system may be set up by subdividing the site into a number of areas equal to the "Irrigation Period" in days and applying the "Application Amount" in one day on one area, then moving the sprinkler laterals to another area and applying the same amount of liquid the next day and so on until the whole site has received an equal amount of liquid within the irrigation period. This cycle is then repeated throughout the spray season. Any rainfall or effluent application which exceed the tabulated application amount will percolate into the groundwater provided the recommended application rate is not exceeded. If the sum of the effluent application and rainfall is less than or equal to the "Application Amount", maximum plant utilization of the effluent nutrients and minimum infiltration to groundwater should occur.

The liquid application amounts for overland runoff systems are based on maintaining a viable growth of microorganisms on the soil and vegetation for effluent biodegradation without creating anaerobic conditions in the root zone. Daily applications of 0.6 to 1.8 cm have been used successfully (9) although data correlating liquid loadings, slope and length of runoff with treatment efficiency is limited.

TABLE 3. MOISTURE REQUIREMENTS FOR PERENNIAL GRASSES*

Soil	Application Amount (cm)	Irrigation Period (days)	Recommended Application Rate (cm per hour)
Well drained sands	3.3	5	0.6 to 1.9
Loamy Sands	4.3	6	0.6 to 1.3
Light Coloured Loams and Sandy Loams and good drainage	5.1	7	0.6 to 1.3
Dark Coloured Loams and Sandy Loams with fair to poor drainage	6.9	10	0.6 to 1.3
Clay Loams	6.1	9	0.4 to 1.0

* from Irrigation Practices for Ontario, OMAF AGDEX 560/753

Experience with OR disposal of municipal waste stabilization pond effluent on a clay soil with a 5 percent slope showed a 90 percent overall reduction of phosphorus and 50 percent reduction in applied volume (11).

3. PILOT STUDIES

3.1 General

An on-site pilot study is recommended for determining the feasibility of land disposal of sewage effluent. Such a study can provide valuable design data (application rates and amounts) particularly in cases where the topography and soil type fall between the preferred conditions for SI or OR disposal.

Studies should be conducted on representative plots of approximately 0.5 hectare selected from topographical and soil maps. Flat plots may be defined by plowing a furrow around the perimeter and mounding the soil on the outer bank; sloping plots require a cleared ditch and flow measuring device (Parshall flume, V-notch weir) at the base of the slope. A network of wellpoint piezometers should be installed in and around flat areas and those sloping areas with more than moderate permeability to monitor changes in watertable and groundwater quality.

The mode of liquid disposal depends on the topography and drainage. Sites for which the physiography does not fall within the boundaries for SI and OR operation as shown in section 2.2, should be able to accept liquid applied by SI with strict control against flooding, particularly on poorly drained flatlands.

3.2 Design and Operation

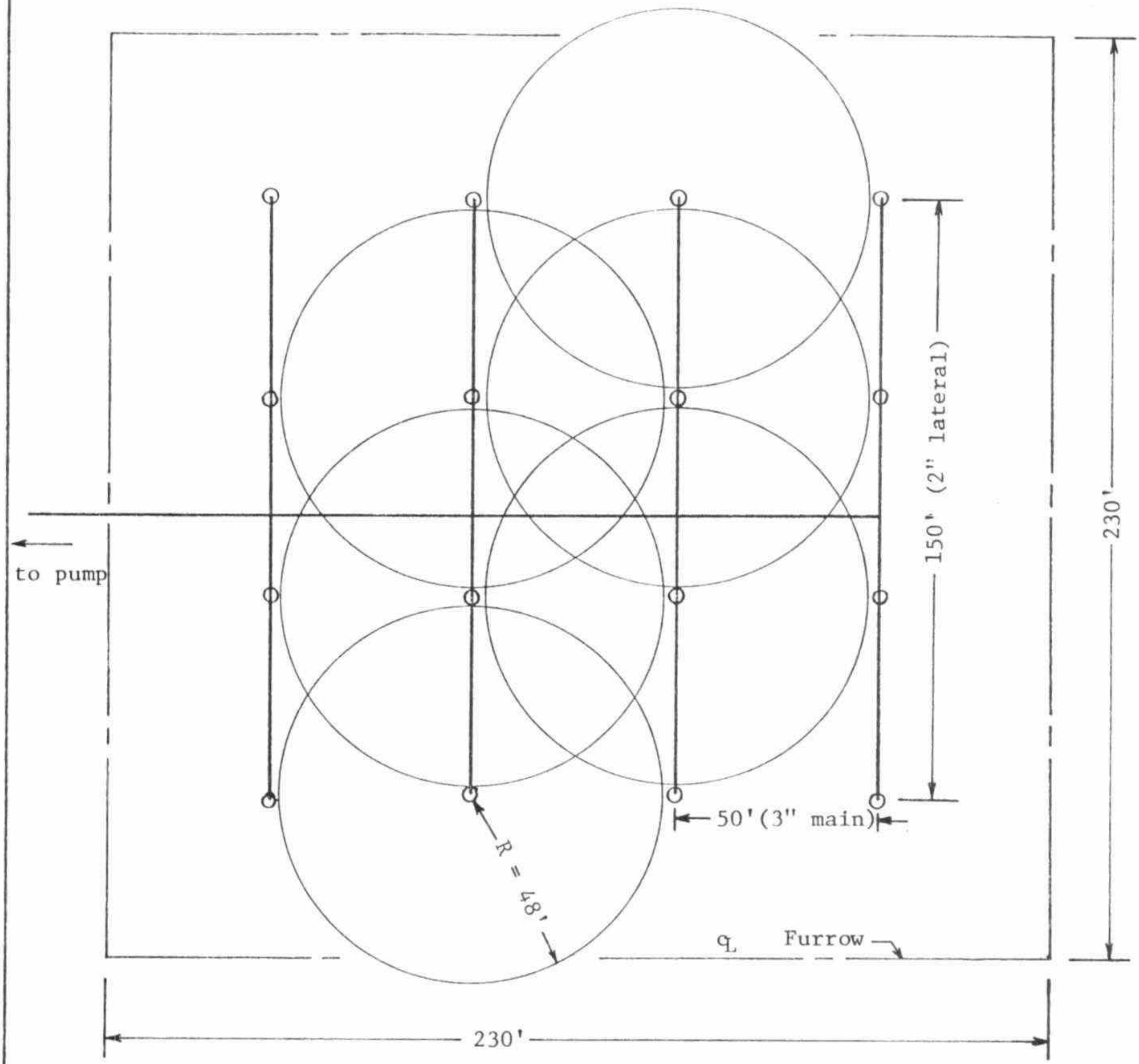
3.2-1 Spray Irrigation

The procedure for an SI pilot study was developed from a test study at Port Rowan (see Appendix). A uniform distribution of effluent may be obtained using a pipe and sprinkler layout as shown in Figure 3 and the equipment listed in Table 4. This layout will provide an application rate of 0.64 cm/hour (0.25 "/hour) at a nozzle pressure of 4.2 Kg/cm^2 (60 psi) and pump discharge of 520 litres/min (114 gpm). Irrigation times for liquid application amounts of 1.0 to 6.0 cm/week are shown below:

Application Amount (cm)	Irrigation Time (hours:minutes/week)
1.0	1:35
2.0	3:10
3.0	4:45
4.0	6:20
5.0	7:50
6.0	9:25

Each amount of effluent (in ascending order) should be applied for a period of three to four weeks per amount on a one day per week basis. Watertable measurements should be taken each week before irrigation and the volume of runoff in the peripheral ditch estimated. Samples of effluent, runoff and groundwater should be analyzed for sewage contaminants (BOD, solids, nitrogen and phosphorus).

The maximum acceptable liquid depth should be that which will maintain the watertable below 2 metres. The volume of liquid should also not ne so great that it causes flooding or erosion; flooding and erosion may be evinced if the suspended solids content of the runoff is greater than that of the applied liquid.



PILOT STUDY

Spray Irrigation System.

Figure 3	Scale 1:480

TABLE 4. EQUIPMENT FOR SI PILOT SYSTEM

Quantity	Item*
10 lengths	3" Al Pipe in 30-ft. lengths c/w couplers.
3 lengths	3" Al Pipe in 20-ft. lengths c/w couplers.
12 lengths	2" Al Pipe in 30-ft. lengths c/w couplers.
21 only	1" Plugs
3 only	M x F 3" Tee with 3" Outlet w/valve.
1 only	3" Mainline End Tee with 3" Outlet w /valve.
4 only	3" Mainline x 2" x 2" Lateral Take-off Tee w/locking lever.
8 only	2" End Plugs w/latch
16 only	1 x 3/4 x 24" Risers with 11/64" x 3/32" - 7° Nozzles (Rainbird 30 EB - TNT)
1 only	Portable Gas-driven Pump (114 gpm @ 65 psi TDH) and ancillary equipment (suction pipe and screen, checkvalve, pressure gauge, adaptor to 3" irrigation pipe)

* Trade names are used as a guide, not an endorsement.

3.2 Overland Runoff

The operation of OR systems differs significantly from that of SI as runoff is encouraged by a heavy local application of liquid from widely spaced (30 to 90 m) sprinkler laterals, perforated pipe or distribution ditches traversing a sloped disposal area. The frequency of application by OR is also greater than SI because of the greater allowable application amounts.

The equipment listed in Table 5 should be installed in a single line along the top of a representative section of the prospective OR disposal site. The three sprinklers on an 18 metre spacing are capable of discharging a total flow of 325 liters /min (71 gpm) at a nozzle pressure of 4.2 Kg/cm^2 (70 psi) over a width of 80 metres. Assuming a length of runoff of 60 metres, the average rate of liquid application is 0.4 cm/hour. Application times for amounts of 2 to 10 cm/week are shown below:

Application Amount (cm/week)	Application Time (hours:minutes)	
	Daily	Weekly
2	0:45	5:00
4	1:25	10:00
6	2:10	15:00
8	2:50	20:00
10	3:35	25:00

Effluent should be applied at each amount, in ascending order, for a period of 3 to 4 weeks per amount on a daily basis to maintain moist, aerobic conditions in the crop-soil system. Quantitative and qualitative measurements of the runoff should be made during each period. A mass balance, using the volumes and pollutant concentrations of the applied effluent and runoff, may be used to determine removal efficiencies.

The maximum acceptable amount of liquid application occurs at the required removal efficiency or at the point when erosion occurs; i.e. when the removal efficiency for suspended solids is less than zero.

TABLE 5. EQUIPMENT FOR OR SYSTEM

Quantity	Item*
10 lengths	3" Al Pipe in 30 ft. lengths c/w couplers
1 only	3" Reversible Field Elbow
1 only	3" End cap
7 only	1" Plugs
3 only	1" x 36" Al Risers TBE
3 only	1" female Part Circle Sprinklers with 11/32" nozzle (Rainbird Model 65D)
1 only	Portable gas-driven pump with capacity of 71 gpm @ 75 psi TDH and ancillary equipment (Suction pipe and screen, checkvalve, pressure gauge, adapter to 3" irrigation pipe).

* Trade names are used as a guide, not an endorsement.

4. SUMMARY

The choice of land disposal for reducing the effluent loading on a receiving stream is based primarily on the availability of large quantities of cheap land, as approximately 63 hectares (155 acres) are required to dispose of 1 MGD at an application rate of 5.1 cm/week (2.0 inches/week).

Local climatic data is used to determine the number of days available for effluent disposal and the volume requirements for winter storage; a 1 hectare (2.5 acre) lagoon 2 metres (6.5 feet) deep will hold 2×10^4 m^3 (4.4 MG). The physiography (soil, topography and drainage) of the site determines the most suitable mode of liquid application. Vegetation on a disposal site is essential for maintaining an open soil structure(SI) and for effluent renovation (OR); perennial grasses, although not a valuable cash crop, are strongly recommended for these purposes.

The liquid application amounts may be based on the moisture requirements for perennial grasses or the results of pilot scale studies. Final design of a full-scale SI or OR system should be obtained from a consultant or an irrigation equipment supplier.

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APPENDIX

TEST STUDY AT PORT ROWAN

1. Purpose

The purpose of the test study was to determine the applicability of the parameters presented in "SITE CONSIDERATIONS" and to develop the general procedure for a spray irrigation pilot study (Section 3.2-1).

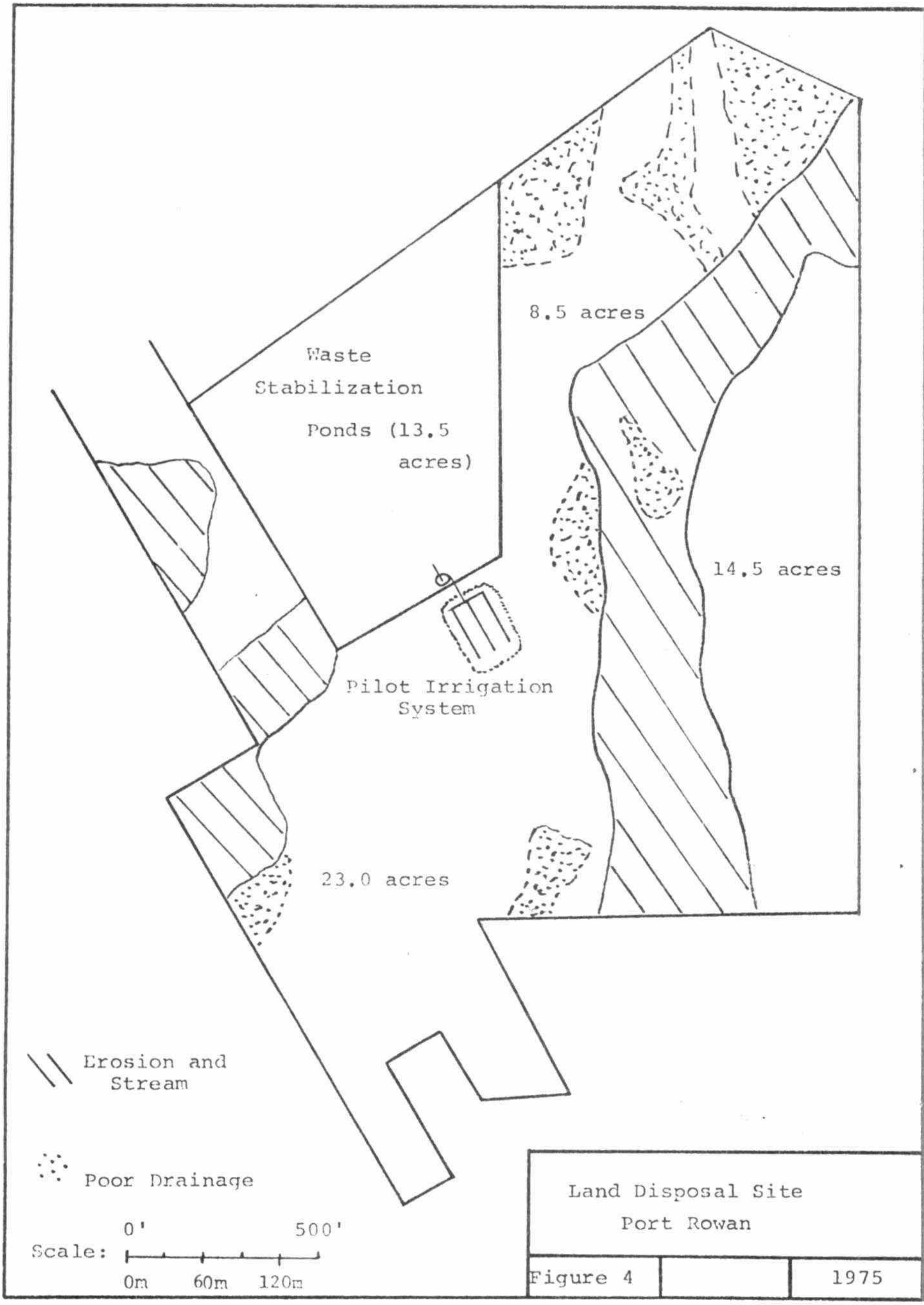
2. General

Sewage treatment for the town of Port Rowan, on the north shore of Lake Erie, is provided by two recently constructed waste stabilization ponds. Land disposal of the effluent was considered as an alternative to phosphorus removal by chemical precipitation in the ponds as it would have the advantage of avoiding seasonal discharges of treated sewage to the shallow bay and thus possibly avoid having to relocate Port Rowan's water intake.

3. Study Procedure

The soil of the municipally-owned land adjacent to the ponds (Figure 4) has a clay texture with "imperfect" drainage, a flat to rolling topography and vegetation typical of fallow pasture; the runoff coefficient corresponding to this combination of topography, soil and cover is between 0.35 and 0.40 (Table 1). The direction of surface drainage is toward a stream running through the site. There were no wells on the site.

The choice of spray irrigation as the disposal method was based on the estimated value of the runoff coefficient. The study procedure was modified by reducing the application rate to a low 0.2 cm/hour and increasing the application time to distribute the liquid load on the imperfectly drained subsoil. Effluent depths of 2, 4 and 6 cm/week were applied for a period of two weeks per


8.5 acres
Waste
Stabilization
Ponds (13.5
acres)
14.5 acres
Pilot Irrigation
System
23.0 acres
Erosion and
Stream
Poor Drainage
Scale:
0'
500'
0m
60m
120m
Land Disposal Site
Port Rowan
Figure 4
1975

depth on a 0.4 hectare plot with a furrow ploughed around the perimeter to collect any surface runoff. Operational data (pumping rates and times), site observations (rainguage and watertable measurements) and sample analyses (effluent, groundwater and runoff) were recorded on log and data sheets similar to those at the end of the appendix.

4. Observations and Results

A heavy rainfall and the applied effluent both combined to raise the local watertable above the 2 metre level and to partially flood the furrow during the first week of operation. The watertable continued to rise during subsequent weeks of irrigation without rainfall, indicating local groundwater mounding. As the watertable approached the ground surface, liquid in the furrow rose to the point of overflow.

Average analyses of the sprayed effluent and liquid in the furrow and the range of groundwater analyses are shown below:

Sample Location.	BOD	SS	Free NH_3	TKN	NO_2	NO_3	Total P	Sol P
Effluent	8	60	0.6	4	.06	.7	1.6	1.2
Furrow	7	25	<0.3	3	.01	<.1	0.7	0.4
Groundwater			0.4	0.2	0.6	0.3	.04	.007
			-.08	-0.8	-0.9	-3.5	-0.2	-.04

The effluent was quite weak as the ponds were partially filled with rainwater prior to start-up. Although the quality of liquid in the furrow would be acceptable for discharge to a receiving stream, it would likely deteriorate as the effluent strength increased. The ranges of groundwater quality are more indicative of erratic behaviour than general increases in nutrient level due to effluent contamination, except in the case of nitrate (NO_3). A statistical correlation between the rise in nitrate and depth of applied effluent was not possible due to insufficient data.

5. Summary

The rise in both watertable and nitrate concentration in the local groundwater were two factors which showed that although infiltration of the effluent could be achieved using an SI system, the imperfect drainage of the subsoil would eventually cause surface flooding. The test study indicated the importance of drainage characteristics of the subsoil and the desirability of quantitative measurements of the runoff. Batch chemical treatment was eventually chosen for phosphorus removal from the pond effluent.

LAND DISPOSAL LOG SHEET

LOCATION:

WEEK ENDING SUNDAY 19

DAY	OPERATION From to	TIME No. hrs.	PUMP PRESSURE OR RPM	RAINGUAGE READING	RUNOFF MEASUREMENT	AIR Max	TEMP Min	COMMENTS
MON.								
TUES.								
WED.								
THURS.								
FRI.								
SAT.								
SUN.								
TOTAL								

LAND DISPOSAL DATA SHEET

SAMPLE LOCATION:

DATE	DEPTH TO WATERTABLE	BOD	SUSPENDED SOLIDS	PHOSPHORUS		NITROGEN				pH	Chloride
				Total	sol.	Free NH_3	Total Kjel	NO_2	NO_3		